

URBAN PLANNING IN MOROCCO: NORMATIVE RIGIDITY, ARCHITECTURAL QUALITY AND THE URBAN HEAT ISLAND PHENOMENON

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ABSTRACT

The functioning of cities is closely linked to the use of available resources and energies. After the Industrial Revolution, the modern, energy-intensive model of the city has since spread widely around the world, and is today a model that has been widely duplicated in developing countries. However, this modern model of the city is no longer suited to today's climate challenges. The phenomenon of the urban heat island (ICU) is one of these challenges generated by several determinants (the densification of the city, planning methods, human activities, the absence of nature in the city, used materials...). According to the Intergovernmental Panel on Climate Change (IPCC), the frequency of extreme weather events such as heat waves will only increase, it is essential that cities integrate these considerations into urban planning and the 'architecture.

Nowadays, our modern constructions in Morocco cannot function without consuming energy, thus generating an economic as well as an ecological impact. Talking about energy sobriety in the building, climatic, and social adaptation, or even thermal comfort, remains difficult to date, as habits and construction methods go against any ecological approach. To orient urban design in favor of thermal comfort in the city, two criteria are necessary: The choice of high-performance technical solutions and the choice of sustainable urban development strategies. For this, the awareness of the energy problem and the depletion of fossil fuels have led to review our way of designing and building. The thermal regulation, which appeared recently within the framework of the thermal regulation of constructions in Morocco, will henceforth become the minimum standard below which it will be prohibited to build or renovate.

Starting from the postulate that urban planning documents have a direct impact on the urban form and the practices of the city that it generates– in the sense that they define the location of human settlements and guide their spatial development– our intervention proposes to study how does urban planning, through urban planning documents influence thermal comfort in the city and the urban heat island.

In this context, it was incumbent on us to question the concept of urban planning and architectural regulations, to read it while understanding it in the context of the energy transition. We dwell on the question of architectural and urban quality in its broadest sense in close connection with the regulations, and we study how the latter can influence the phenomenon of the heat island and thermal comfort in the city. We approach this problem through the case of some Moroccan cities. We will try to see how urban planning documents influence thermal comfort and UIC in these cities and show how they could or did not protect themselves from its risks.

KEYWORDS: Urban Planning, Urban Regulation, Heat Island, Energy Efficiency, Energy Transition

INTRODUCTION

Morocco was among the first countries to adopt an elaborate urban planning system that has long served as a model. This system has played its role fully for a long time. Thus, a good part of the modern city of Marrakech, Rabat, the reconstructed city of Agadir make the admiration of urban planners and reflect in an almost perfect way, the harmony of design and realization which exists between the texts conceived at the base to govern them and the urbanistic and architectural achievements to which they resulted.

However, this concordance is not always present in the sense that large neighborhoods were built in violation of all regulations and urban plans.

In Morocco, urbanization did not increase until the beginning of the century during the French protectorate, which introduced a number of changes to economic, social and cultural structures. This urbanization movement, which has been increasing since the beginning of the century, has created an urban revolution and has transformed the conditions in which people live, which imposed urban planning and architectural regulations, which became widespread to cover the entire national territory using new tools, namely metropolitan master plans for urban development (SDAU). The large master plans developed are representative of the first generation of urban plans and have several common characteristics. They are typical of standardized, functionalist and regulatory town planning (Aljem, 2016).

It is up to us to question certain aspects of town planning and architectural regulations by apprehending them in the context of the energy transition, focusing on the phenomenon of the heat island. Regulating the field of architecture is inevitable but what role does regulation play in the process of producing 21st century architecture? What is its impact on architectural quality? This brings us to the following main question:

How do Town Planning and Architectural Regulations Influence the Urban Heat Island Effect?

Starting from the premise that urban planning documents have a direct impact on the urban form and city practices that they generate in the sense that they define the location of human settlements and guide their spatial development. Our intervention proposes to study how urban planning, through urban planning documents, influences thermal comfort in the city and the urban heat island?

For this, we will deal with this issue through urban planning documents, in particular the Land Use Plan, the Land Use By-law and the constructability indicators. For this fact, we have analyzed the standard terms of reference of a management plan, the application and observation on the ground of certain concrete cases.

This work neither aims to design a new methodology for regulating the field of architecture nor to determine the value of these in regulating the construction universe. Such research would be illusory given the multiplicity of views on the value of architectural regulations. Indeed, the originality of our research lies in the fact that we emphasize the capacity of architectural regulations to be implemented in an operational manner within the complex architectural and urban fabric, and to understand its impact on the energy performance of architecture, and reveal the causal link between architectural regulations and the urban heat island phenomenon.

Energy Transition, an International Bet

The functioning of cities is closely linked to the use of available resources and energies. After the industrial revolution, the model of the "modern" and energy-consuming city has since spread widely on a world scale and has become widely duplicated in developing countries.

According to the International Energy Agency (IEA)¹, the building sector is responsible for 35% of energy consumption worldwide by using fossil fuels as an energy source in buildings (heating, air conditioning, lighting, electrical appliances and equipment, etc.), which also makes it responsible for around a third of global carbon dioxide (CO₂) emissions. The situation is getting worse in developing countries with a building sector that consumes more than 40% of the energy consumed in these countries.² Globally, the overall energy consumption of buildings could reach around 3800 million tonnes of oil equivalent in 2030, about half of which (1800 Mtoe) would come from developing countries.

According to the latest report from the Intergovernmental Panel on Climate Change ³, "the warming of the climate system is unequivocal." This implies that local authorities, developers, architects, property managers etc. The latter must imperatively address the issue of the many territories vulnerable because of global warming.

According to the Intergovernmental Panel on Climate Change (IPCC)⁴, the frequency of extreme weather events such as these heat waves will only increase, it is essential that cities integrate these considerations into urban planning and architecture.

Conceptual Digressions: Architectural Quality and Urban Heat Island

Before tackling the subject of the influence of town planning regulations on the urban heat island, it would first be necessary to define the concept of the heat island and to recall what architectural quality is.

An urban heat island (ICU)⁵ is an urban area whose temperature is significantly higher than that of the surrounding areas. (Anquez, P. and A.Herlem, 2011)

While architectural quality is not a subjective fact. Despite the fact that it is based on a personal position of each on values. These values are scientific, identifiable and governed by regulations. If an architectural trivialization is sometimes seen, it is mainly because architecture is thought out halfway, with a segmented view, from a technical, economic or user point of view only (Hélène Lefranc)⁶

Pierre Larochelle⁷, does not offer a definition of architectural quality, but draws up an analytical framework where he lists five points that all architecture should respect. According to him. There are the ecological aspects (use of resources, materials and energy), social (values and lifestyle of users, constructive practices governed by cultural habits and tastes), operational (i.e. functional), perceptual (impact of architecture on the senses, including thermal and acoustic comfort) and experiential (in particular the phenomenology of space).

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Architectural quality is linked to thermal comfort. It is the contemporary translation of a program that does not renounce any of the criteria that have made architecture an everyday art for millennia. There are as many timeless conditions including the notion of comfort, specificities of use, culture and societal, economic and environmental dimensions.

All those involved in current architectural production must be aware of the importance and the urgency of including the measures of ecological transition (Project manager, project owner, users, decision-makers, urban planners, etc.)⁸. This pressing aspect is particularly noticeable in the current realization of architecture. This pressure has often been expressed by the abundance of well-intentioned regulations specifying, advocating, quantifying and evaluating architectural products from a strictly technical point of view. Architectural quality in the 21st century cannot be limited to a purely technical expression., but can be identified by the four criteria below (Pierre Larochelle):

- **Sustainability:** it is the intelligence of a program well suited for a site and a budget through the prism of sustainable development.
- **Contextualization:** upstream integration of the local context into the architectural project (climate, culture, materials, mode of use, memory of the place, climate, materials, local know-how,...).
- **Originality:** it is the ability to refuse programs and standard plans, because quality architecture cannot be thought of as a product. It is the possibility of innovation by providing conceptual responses other than those already made (VMC or the interior air conditioning system for example...).
- **Sobriety:** it is to design the whole architectural project so that it is frugal in its consumption of energies and resources. That is to say, to anticipate all the possible energy needs of the project from its realization to its use.

From the Traditional City to the Heat Island in Town Planning

Nowadays, our modern constructions in Morocco cannot function without consuming energy, thus generating an economic as well as an ecological impact. Talking about energy sobriety in the building and climatic and social adaptation, or even thermal comfort, remains difficult to this day, as the habits and the constructive modes go against any innovative ecological approach.

Several determinants contribute to the phenomenon of the urban heat island (ICU) (the density of the city, planning methods, human activities, nature in the city, the materials used, etc.). To guide urban design for the benefit of urban comfort, two determinants are necessary: The choice of high-performance technical solutions with multiple benefits (environment, health, landscape integration and quality of life, etc.), and the sustainable choice of urban development strategies.

The awareness of the energy issue and the depletion of fossil fuels has led to a review of the way we design and build. The thermal regulations⁹ that appear today will now become the minimum standard below which it will be prohibited to build or renovate in Morocco. Still it should be used appropriately and not as an approach to follow in a trend movement, especially since it should not be considered as an approach reserved for a few elitist individual houses, but as a mode of construction applicable to all buildings ranging from individual or collective housing to tertiary buildings.

Reading the research works informs us about the multiplicity of approaches according to which the subject was approached.

In the book entitled *Climat & Urbanisme : La relation entre le confort thermique et la forme du cadre bâti*¹⁰ (*Climate & Urbanism: The relationship between thermal comfort and the shape of the built environment*), it deals with urban design adapted to a hot and dry climate. This project, carried out in collaboration between the Public Laboratory for Testing and Study (LPEE) in Morocco and the Department of Housing Development & Management of the University of Lund in Sweden, suggests that the morphology of the urban fabric has a great impact on the microclimate and therefore influences the outdoor thermal comfort of the inhabitants. At the same time, the interior climate of architecture is indirectly influenced by the urban microclimate. The lack of good climate management of the urban environment leads to the excessive use of active air conditioning to meet usage needs and thus aggravates the environmental problems linked to energy consumption. *Sur les traces des pratiques et de savoir-faire éco-responsables : Architecture et Urbanisme traditionnels au Maroc*¹¹ is another work which brings together in a single document good practices and traditional know-how in architecture and urbanism in order to capitalize on them for inspire. The goal is to invoke them in contemporary architecture. Far from reproducing the old models, these are undoubtedly lessons that have much to teach us in terms of urban development and sustainability. For optimal application of the Thermal Construction Regulations in Morocco, ADEREE¹² has developed a guide of good practices for energy efficiency in buildings, intended for building owners, project managers, building professionals, as well as for any potential user. The good practices of Energy Efficiency in the building therefore brings together a range of practices and gestures arising from the Thermal Regulations for Construction in Morocco (RTCM), relating in particular to the choice of thermal insulation, orientation of buildings, ventilation, heating and air conditioning systems, lighting, solar thermal water heaters as well as the choice and use of household appliances. These good practices and energy efficiency measures will guarantee a harmonious implementation of the RTCM. They will ensure in the residential and tertiary sector a reduction in the electric bill, a reduction in the environmental impact, while promoting optimal living comfort, especially thermal comfort, for users of the city.

Town Planning and Architectural Regulations and their Impact on the Urban Heat Island

In the context of urban planning and city management, it is incumbent on us to question certain aspects of urban and architectural regulations by understanding them in the context of this energy transition, focusing on the phenomenon of the block heat. This brings us to the following main question:

- How do urban and architectural regulations influence the heat island?

No regulation alone produces architectural quality. It is recognized that urban planning regulations have a direct impact on the urban form it generates.

- Is this causality also evident in thermal comfort?

The Development Plan and the Imprecision of Sustainable Urban Planning

Starting from the premise that urban planning documents have a direct impact on the urban form and city practices that they generate in the sense that they define the location of human settlements and guide their spatial development. Our intervention proposes to study how urban planning, through urban planning documents, influences thermal comfort in the city and the urban heat island?

We will deal with this issue through the urban planning documents, in this case, the Land Use Plan, and the constructability indicators. To do this, we have analyzed the standard terms of reference of a management plan, the application of its regulations in specific cases, and the observation in the field of certain cases.

The development plan has a major impact on the urban form of the Moroccan city by defining the right to the soil through the regulations applicable to construction, the easements to be respected, the zoning and the constructability indicators. We wondered how the management plan addresses the issue of energy efficiency. Reading the terms of reference which are the contractual description of the implementation and design of a management plan allowed us to raise article 5 entitled: Principles of intervention, which is based on The definition of sustainable development encompassing its three pillars: the economy, the environment and social equity.

Sustainable urban planning¹³ through the development plan, as described in the terms of reference, deals with sustainability in general without specifying the needs of the citizen, the conditions of a dynamic economy, the efficient way and appropriate use of the land, without quantifying the density, intensity, activity and use, without listing the principles of energy efficiency. It is therefore partially responsible for the phenomenon of the urban heat island.

The Planning Regulations

What about the planning regulations which control the subject of the urban form, and therefore the urban heat island? Let us recall that the planning regulations impose the constructability indicators which concern the COS, the CUS, and the height per zone as seen in the example of the table below:

Table 1

	Soil Occupancy Coefficient (COS)	Coefficient of Soil Exploitation (CES)	Min Parcel	Height
D1	1	50 %	200 m ²	2 Floors
B3	2,4	70 %	200 m ²	4 Floors

Its objective being to Prohibit the activities, to limit the COS / CUS / height, to limit the architectural cachet / Parking.

It establishes the Concept of ground density by circumscribing the relationship between the buildable surface and the land, and by specifying the density of occupation on the ground (total number of dwellings / perimeter.

Art. 5 Principles of intervention

1- Sustainable urban planning.

“It is through the study of the development plan to highlight the principles of sustainable urban planning consisting of taking into account aspects relating to economic and social development as well as the environmental balance of the area concerned.

It consists of a process by which all actors work together to design and plan an environment that:

Ensures the population a safe, suitable living environment capable of satisfying the needs and expectations of citizens in their diversity;

Create the conditions for a dynamic, balanced, inclusive and fair economy;

Social, cultural and economic considerations;

Promotes modern, energy-efficient approaches that meet the principles of preservation and protection of agricultural, natural and forest areas and the ecological imperatives of urban development;

Preserves natural resources, heritage and landscape.

Advocates the principles of energy efficiency in planning methods.

Integrates and prevents natural, industrial and technological risks.

Land as a precious resource to be used in the most efficient and appropriate way, thus avoiding sprawl and dispersal of peripheral areas;

Reconcile the two modes, that of urban renewal and urban extension while preserving the balance between the center and the periphery;

Has enough density, intensity, activity and use for services such as public transport to be viable and efficient and for travel times to be optimized;

Control the needs for travel and urban mobility while integrating the principles of multimodal accessibility and their social impacts;

Has planned, quality infrastructure to create good integration conditions.”

Buildability Indicators (Prospect, COS and CUS)

The Prospect in Morocco

A prospect is a town planning measure organizing volumes in the city. The objective of this rule is to guarantee sunshine, eyesight and hygiene for each construction, by fixing minimum distances between buildings and their heights. The prospect has a major impact on the urban morphology and the heat island. The prospect is now an integral part of Moroccan town planning legislation. However, the urban planning regulations in Morocco are French inspired, and the prospect rule which equals or exceeds the height of the buildings corresponds to the French environment with a lower incidence of the sun than in Morocco ignoring the specific environmental characteristics of Morocco.

In order to compare the incidence of the sun in connection with the prospect and the phenomenon of the heat island, we are based on the calculation of the position of the sun in the sky for two locations on the earth at identical times of 1 year to determine the prospect needed.

We took a first case study, where we chose the city of Paris in France on March 29, 2018 at 12 p.m. and a second case of the city of Rabat in Morocco at the same time. The rise of the sun at the same time of the year is 45 ° in Paris while in Rabat, it is 59 °.

The data chosen for our case studies are real data based on information from the sunearthtools¹³ measurement tool grouping together a Collection of tools to know and work with solar energy. Calculation of: the position of the sun, the coordinates of longitude, latitude, photovoltaic systems, CO2 emissions.

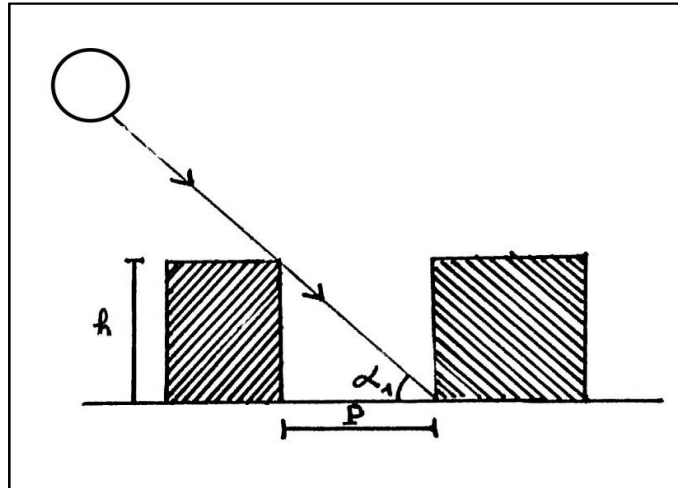


Figure 1: Incidence of the Sun and Prospect in Case 1 (Paris).

α : The height of the sun in

P : Regulatory prospect

h : building height

In our case study 1, $\alpha = 45^\circ$

We will take the example of a building of $h = 12\text{m}$.

$$P = h / \tan(\alpha)$$

$$P = 12 / \tan(45) = 12\text{m}$$

The prospect in this case equals the height of the building.

α : The height of the sun

P : Prospect

h : building height

d : prospect required

In our case 2, $\alpha = 59^\circ$

We will take the same example of a building of $h = 12\text{m}$.

$$d = h / \tan(\alpha)$$

$$d = 12 / \tan(59) = 7.22\text{m}$$

$$d < P$$

The prospect in this case is greater than the shaded distance (prospect required) overexposing the avenue to the sun, and contributing to the phenomenon of the heat island.

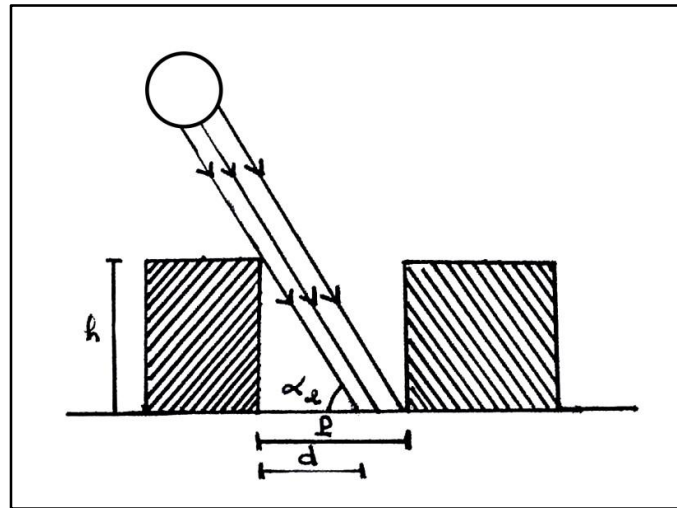


Figure 2: Incidence of the Sun and Prospect in Case 2 (Rabat).

The minimum prospect requirement can favor the joint ownership of buildings and therefore a compact urban form favoring energy performance.

Urban Density

A comparison of the urban fabric between a modern district exploded in Fez (Seffarine district, fig.3 on the left) and a traditional compact district (Adarissa district, fig.3 on the right).

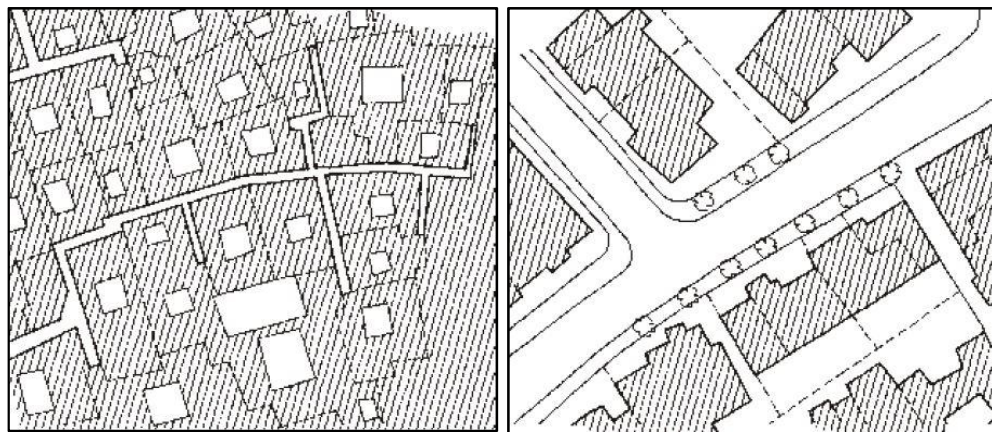


Figure 3: Comparison of the Urban Fabric of the Modern District (Left) and the Traditional District (Right). the Gray Parts Represent The Streets and Courtyards, the White Parts Represent the Houses. The Districts are Presented on the Same Scale. ^{14 15}

In the Seffarine district, the entire area occupied by streets and courtyards represents approximately 1/3 of the total area and, given the density of the constructions, it can be estimated that less than 1/3 of the ground is in sunshine during the day. In the Adarissa district, the entire area occupied by streets and courtyards represents approximately 2/3 of

the total area, and only 1/3 of the ground surface is occupied by residential buildings. The difference in density of neighborhoods implies differences on the following factors, which in turn influence the micro climate:

- Sunshine and sun protection,
- The long wavelength radiation towards the sky,
- Thermal storage,
- Wind protection.

It can be seen that the temperatures fluctuate upward and downward in the case of modern burst fabric, while the temperatures in the traditional compact fabric is more or less stable. The two districts show significant differences in air temperatures. Compared to the modern, bustling neighborhood, the traditional compact neighborhood is colder during the day, and warmer at night.

The link between the compactness of the city and the urban heat island is direct. The more a city is spread out, like most modern cities, the more the phenomenon of the urban heat island is important and Conversely for the cities "compact", where the heat dissipates easily.

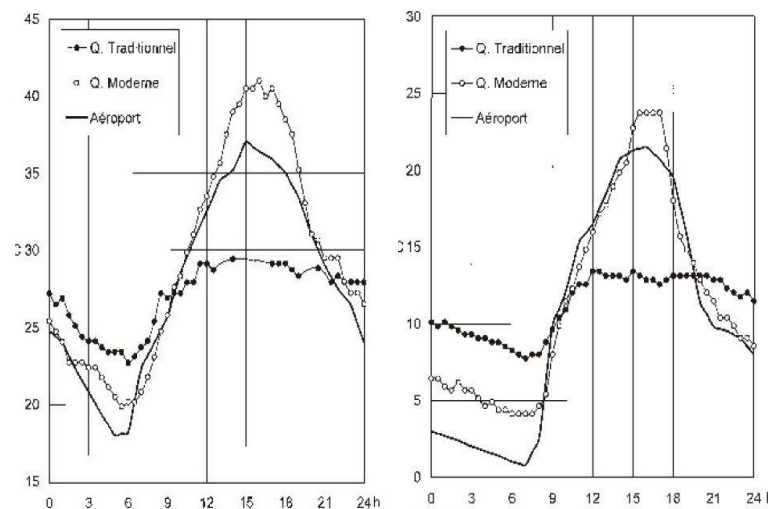


Figure 4: Air Temperatures Recorded in Residential Areas and at the Airport During a Winter Day (February 10, Left) and Summer Day (June 29, Right).

Urban expansion or density directly influences the heat island. The more a city is spread out, like most cities in the world, the greater the phenomenon of the urban heat island (the heat remains trapped). Conversely for "compact" cities, including the hearts of historic cities where the heat Evacuates easily according to the study published in Physical Review Letters in March 2018¹⁶, As well as in the report of the cooperation project, University of Lund, Sweden - LPPE, Morocco (Climate & Urbanism: The relationship between thermal comfort and form of the built frame). Sophie Debergue¹⁷ insisted that it is essential to act as far upstream as possible, via urban planning documents, and to this end, to mobilize all the services of the community: roads, town planning, green spaces, energy, environment, water".¹⁸

In general, the sprawl of cities associated with their densification means that the heat island phenomenon must be understood more generally. A territory-wide strategy must be established through adequate planning and development. These measures must be reintegrated into the development, restructuring and upgrading plans of cities.

Urban expansion or densification has a direct influence on the heat island.

Unconstructed Space (Green Space)

The vegetation in the city, imposed by town planning regulations, is designed to decorate avenues and streets. Considered for its purely picturesque and aesthetic virtues, the trees are posed to embellish avenues and streets, without considering the concern of shading and protecting from the sun and bad weather. The species chosen for this purpose are certainly adapted to our climate, perhaps even carrying a symbolic connotation of the country, but do not ensure its role for thermal comfort in the city. (Example: Eucalyptus replaced by the Washingtonias to embellish Med 6 avenue with flaps).

The spacings between the plant articles leaves something to be desired, omitting the incidence of the sun and the practice of city users, and integrate our urban roads overexposed to the sun accentuating the phenomenon of the heat island.

And yet, in an urban environment, Plants participate in the cooling of the air thanks to the projection of shade and the mechanism of evapotranspiration. The shade produced by the plant reduces the temperature of the ground and of the facades of buildings by absorbing the share of solar energy it receives.

Trees receive the incidence of the sun's rays and reflect the radiation emitted by the surrounding surfaces. The air is refreshed by the evaporation of water in the soil and plants in addition to the perspiration of the leaves.

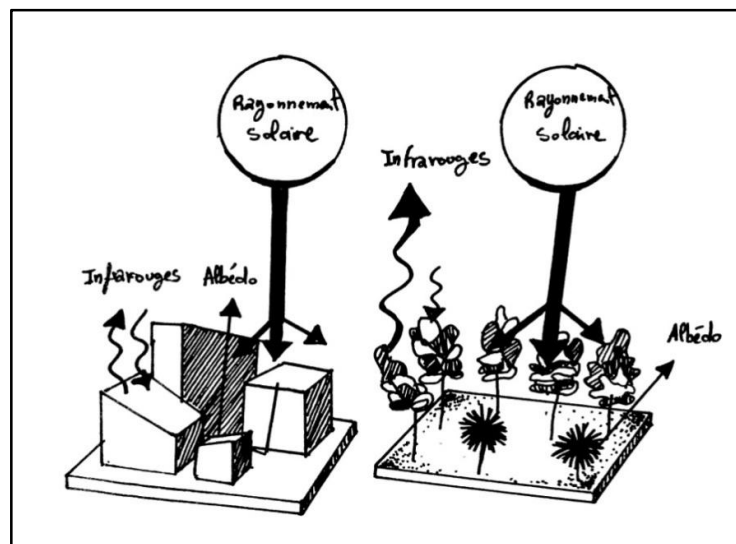


Figure 5: Comparison of Warmth between a Predominantly Built Urban Fabric (Left) and a Green Space (Right).

Vegetation also contributes to the reduction of the greenhouse effect thanks to its photosynthesis mechanism. Through this characteristic, the leaves of chlorophyllian plants absorb carbon dioxide CO₂ which reduces the concentration of this greenhouse gas in the air and releases oxygen into the air.

Street Orientation

The urban heat island is closely linked to traffic or the absence of wind. A strong wind will favor the movement of air, which will decrease the warming of the urban substratum by hot air. On the other hand, a weak wind will lead to a stagnation of the masses warming the urban space.

Thus, the more the climate is calm and clear, the more intense the urban heat island or vice versa. Especially since the urban form plays on the performance of the winds: a narrow and narrow street, forming a canyon, prevents the winds from circulating and then causes the air masses to stagnate. This is why it is imperative to take into account the direction of the prevailing winds in the orientation of the streets decided by the development plan.

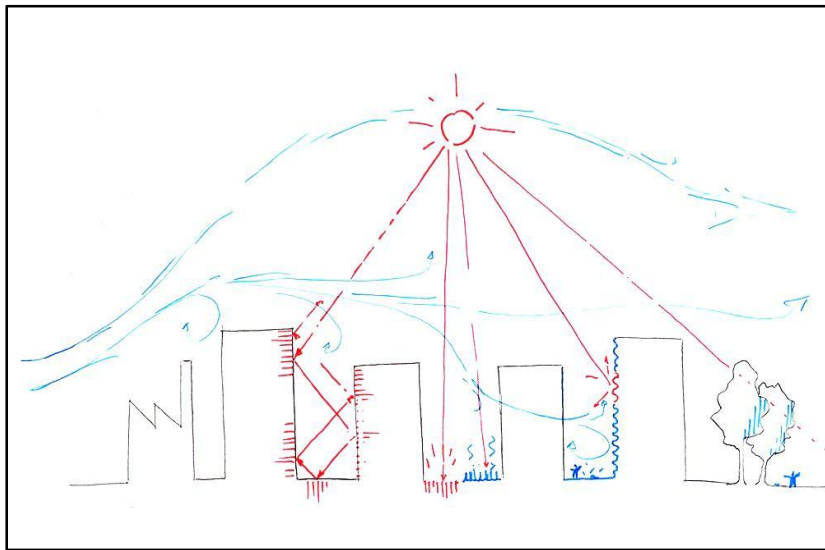


Figure 6: Performance of Winds in Urban Areas (Rue Canyon).

Artificial Soil

The coatings used in the city prescribed for the roads laid down by urban planning regulations are composed of impermeable surfaces such as asphalt having taken the place of the natural soil, the aquatic and plant element. Heat is absorbed more quickly and evaporation is slower. The dark blackish color of bitumen contributes to this heat island phenomenon. The more a material absorbs the sun's rays, the more it accumulates and emits heat (low albedo¹⁹). This is the case of spaces covered with mineral materials. Thus paved roads and parking lots, tarred roofs, brick walls, etc. are important contributors to the formation of urban heat islands.

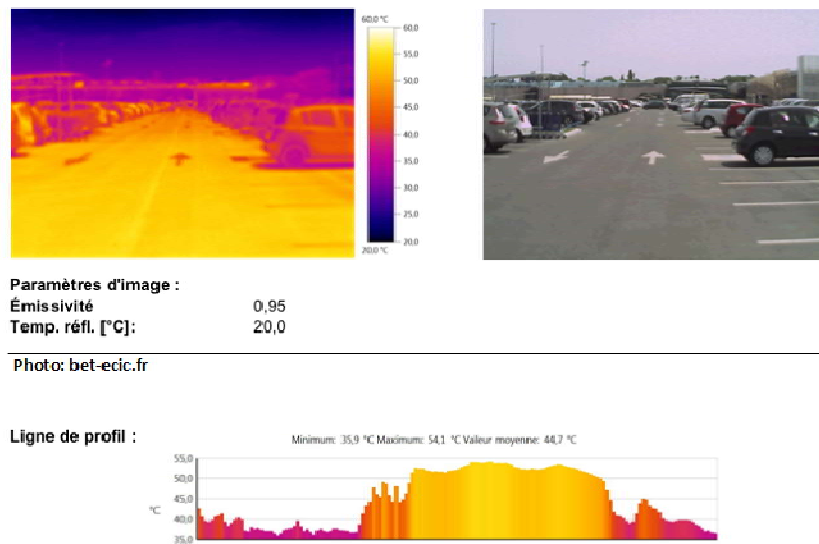


Figure 7: Example of Temperature Profile in a Shopping Center Parking Lot.²⁰

The example of the Los Angeles municipality favored light colors for city floor coverings in order to cool the temperature. It opted for “cool pavements”: by coating some of its streets with less absorbent gray white paint, called CoolSeal, the ground temperature could drop by around 7 ° C ²¹.

The same principle applies for building facades. It is possible to play on the building envelope, by lowering the surface temperature of the materials. During a heat wave episode, a dark roof can reach 80 ° C, while a light roof stops at 45 ° C. Green roofs score even less when passing below 30 ° C.

CONCLUSIONS

It is clear that the energy transition in terms of town planning and architecture and their implementation, first passes through the establishment of reformed planning and town planning policies, including the documents of the town planning regulations are the expression.

Sustainable spatial planning and development is the most crucial lever in the energy transition and alone guarantees the reduction of energy demand. Decreasing demand on this scale would have a greater impact and represent much more important levers than measures on supply.

The efficiency of energy planning must be supported by adequate and complementary consideration by urban planning documents. Close collaboration between the various actors in the building process is therefore necessary. Energy and climate being remarkably cross-cutting issues, each territorial level, each planning document, each town planning regulation, each actor, influences the achievement of this objective.

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